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UNITED STATES PATENT APPLICATION

OF

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FOR

OPACITY ENHANCEMENT OF TISSUE PRODUCTS WITH THERMALLY EXPANDABLE MICROSPHERES

OPACITY ENHANCEMENT OF TISSUE PRODUCTS WITH THERMALLY EXPANDABLE MICROSPHERES

The present invention is based on provisional patent application Serial Number 60/171,031 filed December 16, 1999, and priority is hereby claimed therefrom.

Field of the Invention

The present invention generally relates to a method of incorporating thermally expandable microspheres into tissue products so that the resulting products have increased opacity. More particularly, the present invention is directed to the incorporation of thermally expandable microspheres into the wet end of a tissue manufacturing process so as to impart increased opacity to tissue products such as bath tissue, facial tissue, and towels.

Background of the Invention

As lower basis weight tissue products evolve, new technical challenges are created since many physical properties of tissue products depend on the number and compactness of fibers present in the structure after consolidation. The opacity or "see-through" of tissue products is becoming a limiting factor in fiber assemblies that utilize fewer fibers while maintaining the same or superior strength as traditional fiber assemblies. Obviously, consumers desire that such products have sufficient opacity to prevent substantial see-through in the product.

Many different processes and compounds have been identified which can affect the opacity of paper (as opposed to lighter weight tissue) products. The measure of opacity in a finished sheet of paper depends on the evaluation of diffuse reflectance (R), which in turn is related through the Kubelka-Munk (K-M) theory to the scattering (s) and absorption (k) coefficients of the elements in the fibrous structure. These are basic properties that are intrinsic to the medium.

In its simplest form, paper is an ensemble of fibers more or less bonded to one another in zones of partial optical contact. There are many interfaces between the solid particles and the air, located all across the section and in many different angles. Light coming into contact with paper will diffuse accordingly: a portion will be reflected, some will be absorbed and the rest will be transmitted. This diffusing effect depends on the difference between refractive indexes of the adjoining faces and the number of such interfaces.

Photoelectric instrumentation is used to evaluate spectral reflectance. Several commercial models are available, and depending on the type of backing used below the paper specimen during measurement, different reflectance modes can be characterized. From the standpoint of opacity, three of them are relevant: R_0 when the specimen is backed by a black-velvet lined cavity ("black body"), R_∞ when the backing consist of a thick-enough opaque pad of the same material, and $R_{0.89}$ when measured against a composite (sandwich) formed by a layer of pure magnesium oxide covered by glass, having an effective reflectance of 89% of that of a pure magnesium oxide surface.

In papermaking, opacity is defined as a contrast ratio between reflectances of the sheet over white and black backgrounds. For example, the ratio between R_0 and $R_{0.89}$ is known as “Tappi Opacity”. If the white body is an opaque pile of the paper under examination, the ratio between R_0 and R_∞ is called “Printing Opacity”.

Assuming a homogeneous sheet, opacity (measured as $R_0/R_{0.89}$ or R_0/R_∞) can be unambiguously characterized in terms of the K-M theory intrinsic parameters (s and k), and in particular the elements sW and k/s. The first represents the scattering power (W is the basis weight of the sheet), and the latter determines the reflectivity R_∞. Some equations evolving from the K-M model are:

$$R_\infty = 1 + k/s - \{2\,k/s + (k/s)^2\}^{0.5}$$

and

$$R_0 = R_\infty \{e^{A} - 1\} / \{e^{A} - R_\infty^2\}$$

where $A = sW\,(1/R_\infty - R_\infty)$

Opacity will increase with increasing sW values and with decreasing k/s ratios as published elsewhere. Manipulation of the equations from the K-M theory lead to:

$$Opacity = [100\,(B - 1)] / (B - R_\infty^2)$$

where $B = [R_\infty\,(1 - R_0 R_\infty) / (R_\infty - R_0)]$

Similarly for the scattering power, sW, a set of equations follows:

$$sW = \ln[(X + 1) / (X - 1)] / 2\,b$$

where $X = (1 - a\,R_0) / b\,R_0$, $a = 0.5\,[(1/R_\infty) + R_\infty]$ and $b = 0.5\,[(1/R_\infty) - R_\infty]$

These equations can be solved analytically or using known graphical methods. But if the optical properties of different grades of paper can be well characterized using K-M mathematical model, changing those properties in a practical, cost-efficient way is more complicated. For pulps that underwent a given pulping and bleaching process, it is not easy to change reflectance properties unless

additives are used in the furnish, such as dyes to modify the absorption coefficient and fillers or pigments to increase light scattering. Increasing the basis weight is also a possibility but this is against the current technological trend to lighter tissue products.

An alternative that has been less exploited to increase opacity in paper products is the manipulation of the apparent density of the fibrous structure. Giertz showed a linear inverse relationship between density and specific scattering coefficient, since a higher density represents fewer voids in a structure (in Formation and Structure of Paper, p.597, 1962). El-Hosseiny *et al.* confirmed that over a broad range, the scattering coefficient (s) relates to density (D) following the expression:

$$s = m - n D$$

where m and n are constants (*Tappi* **62**(10):127).

Traditional approaches to increasing the opacity of lightweight fibrous materials, such as tissues, include the use of particulate fillers (such as Kaolin or calcium carbonate) and the use of debonders. Also, microspheres that are not thermally expandable have been used as compounds to aid in increasing the opacity of tissue products. However, desired levels of opacity are not always met by such more traditional methods of opacity enhancement when lightweight tissue grades are involved. Properties such as strength, softness, and low lint requirements become limiting factors in tissue grade applications.

Thermally expandable microspheres have been available for more than a decade; however, they have not been linked to opacity enhancement. U.S. Patent No. 5,155,138 to Lundquist is directed to expandable thermoplastic microspheres themselves and a process

for the production and use thereof. This patent does not mention opacity at all. Similarly, U.S. Patent No. 4,477,518 to Cremona et al. is directed to coated papers and cardboards that comprise a coating layer containing hollow expandable microspheres. This patent also does not mention increased opacity, and the papers described therein are not tissue products.

Most of the art relating to the utilization of thermally expandable microspheres involve applications of these microspheres outside of the low basis weight tissue products field. For example, U.S. Patent No. 4,006,273 to Wolinski et al. is directed to raised printing of fabrics, while U.S. Patent No. 4,044,176, also to Wolinski et al., is directed to a graphic arts media application involving the use of thermally expandable microspheres. Japanese Publication application No. 90/76,735 is directed to slightly rough-textured sheets involving these microspheres, while EP 0 549 948 is directed to the use of thermally expandable microspheres in smooth, anti-slip coatings.

A recent paper suggested the use of expandable microspheres as a bulking/stiffening aid in heavy weight boxboard production. See Ö. Söderberg, "Expandable Microspheres in Board," *World Pulp & Paper Technology*, 1995/96, at 143. Board machine trials revealed that 1% of EXPANCEL® (a commercially available thermally expandable microsphere) is equal to about 18-25% of cellulosic fiber when comparing volume. This same technology can be applied using appropriate microsphere grades to produce stiffer printing, writing, or other fine papers. Such fine papers usually have higher basis weights of about 60 grams per square meter ("gsm") to about 80 gsm which are well above the about 30 gsm upper basis weight limit for the presently-described tissue products.

Other known applications of expandable microspheres include

the formation of sound-absorbing three-dimensional structures, stiffer printable papers, printing substrates, non-slip coatings, elastomeric fabrics, tapes, insulating materials, reinforcing materials, high-grip surfaces, molded articles, and sealing gaskets.

U.S. Patent No. 4,619,734 to Andersson relates to the use of expandable microspheres in low basis weight materials. However, this patent is directed to the production of creped multilayered sanitary paper with increased bulk softness, wherein the majority of the microspheres are precisely located in the middle layer (lower modulus structure, more flexible, less stiff). This patent does not mention opacity at all, but instead focuses on higher softness levels of the sanitary paper web. Also, Andersson requires the use of relatively large amounts of the expandable microspheres, specifically from 1% to 10%.

Thus, a need currently exists for a process wherein tissue products are created that have enhanced opacity.

Summary and Objects of the Invention

It is an object of the present invention to form opaque tissue products through the incorporation of thermally expandable microspheres into such tissue products while they are being manufactured.

It is another object of the present invention to create opaque tissue products of lower basis weights than higher basis weight opaque tissue products currently available.

Some of the above-mentioned objects and, perhaps, other objects are accomplished by incorporating thermally expandable microspheres into low basis weight tissue products (i.e., less than about 30 gsm). The thermally expandable microspheres may be added in the wet end of a tissue manufacturing process prior to forming the tissue web. In certain embodiments, the expandable

microspheres may be added just in front of or at the headbox during the wet end of the paper making process.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description, including the drawing, and the appended claims.

Brief Description of the Drawing

Figure 1 is a schematic flow diagram of a wet-pressed tissue making process.

Detailed Description of Preferred Embodiments

Reference now will be made in detail to the embodiments of the invention, one or more examples of which are set forth below. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment, can be used on another embodiment to yield a still further embodiment.

Thus, it is intended that the present invention cover such modifications and variations as come within the scope of the appended claims and their equivalents. Other objects, features and aspects of the present invention are disclosed in or are obvious from the following detailed description. It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention, which broader aspects are embodied in the exemplary constructions.

The present invention involves the use of thermally expandable microspheres for restoring or enhancing the opacity

levels of tissue products. In addition, the present process is applicable to the use in any wet-end chemistry application that is pertinent to the production of strong, soft, low-lint, absorbent tissue materials that may or may not exhibit other properties such as odor control, anitmicrobial efficacy, etc. Such tissue products may include bath tissue, facial tissue, and towels. The tissue products of this invention can be single-ply products or multi-ply products, such as two-ply, three-ply, four-ply or greater. One-ply products are advantageous because of their lower cost of manufacture, while multi-ply products are preferred by many consumers. For multi-ply products it is not necessary that all plies of the product be the same, provided at least one ply is in accordance with this invention.

Papermaking fibers for making the tissue product webs of this invention include any natural or synthetic fibers suitable for the end use products listed above including, but not limited to: nonwoody fibers, such as abaca, sabai grass, milkweed floss fibers, pineapple leaf fibers; softwood fibers, such as northern and southern softwood kraft fibers; hardwood fibers, such as eucalyptus, maple, birch, aspen, or the like. In addition, furnishes including recycled fibers may also be utilized. In making the tissue products, the fibers are formed into a pulp furnish by known pulp stock formation processes.

Softening agents, sometimes referred to as debonders, can be added to the tissue making process to enhance the softness of the tissue product. Such softening agents can be incorporated with the fibers before, during or after dispersing the fibers in the furnish. Such agents can also be sprayed or printed onto the web after formation, while wet, or added to the wet end of the tissue machine prior to formation. Suitable softening agents include, without limitation, fatty acids, waxes, quaternary ammonium salts, dimethyl dihydrogenated tallow ammonium chloride, quaternary ammonium methyl sulfate,

carboxylated polyethylene, cocamide diethanol amine, coco betane, sodium lauryl sarcosinate, partly ethoxylated quaternary ammonium salt, distearyl dimethyl ammonium chloride, polysiloxanes, silicones, and the like. Examples of suitable commercially available chemical softening agents include, without limitation, Berocell 596 and 584 (quaternary ammonium compounds) manufactured by Eka Nobel Inc., Adogen 442 (dimethyl dihydrogenated tallow ammonium chloride) manufactured by Sherex Chemical Company, Quasoft 203 (quaternary ammonium salt) manufactured by Quaker Chemical Company, Arquad 2HT-75 (di(hydrogenated tallow) dimethyl ammonium chloride) manufactured by Akzo Chemical Company, C-6027 (blend of cationic and non-ionic surfactants) manufactured by Goldschmidt Incorporated, and Prosoft TQ 1003 (quaternary ammonium salt) manufactured by Hercules, Inc. Suitable amounts of softening agents will vary greatly with the species of pulp selected and the desired characteristics of the resulting tissue product. Such amounts can be, without limitation, from about 0.05 to about 1 weight percent based on the weight of fiber, more specifically from about 0.25 to about 0.75 weight percent, and still more specifically about 0.5 weight percent.

The thermally expandable microspheres that are added to the tissue products may be obtained from various manufacturers such as Akzo-Nobel, Pierce & Stevens, Casco, and Dow Chemical. In certain embodiments, EXPANCEL®, a thermally expandable microsphere-containing product, may be incorporated as a wet-end opacity-enhancing additive as a tissue is being formed.

The use of such expandable microspheres allow the opening up of the paper structure so as to create a bulkier (i.e., less dense) web that will scatter light more efficiently. Accordingly, when expandable microspheres are utilized in a paper product, the

resulting paper product will have a bulkier structure than the same paper product at the same weight basis, that will have a higher light scattering coefficient (or higher opacity at any given basis weight).

While the present inventive process is applicable to any form of papermaking machine configuration, any process of paper formation and including single or multilayered web constructions (either with or without pressing, with or without creping, etc.), the microspheres are typically incorporated just in front of or at the headbox during tissue product formation. However, they may be added anywhere in the wet end prior to forming the web. The incorporation of the microspheres results in a tissue product that is better able to scatter light, which translates into a higher opacity over the same basis weight material without the microspheres.

In one particular embodiment of the present invention, 1% by weight (based on the weight of pulp fibers) of EXPANCEL® is added to a softwood fibers furnish, and opacity is increased by almost six units in standard 60 gsm handsheets. (Although 60 gsm handsheets were utilized in the testing set forth herein under TAPPI method T205 sp-95, the light scattering data — which is independent of basis weight -- is applicable to the inventive lighter weight products as well.) In other embodiments, EXPANCEL® is added into a softwood fibers furnish at an amount of about 15 lbs. of microspheres for every 2880 lbs. of paper product produced. In other embodiments, 0.5% by weight of EXPANCEL® microspheres were employed.

Currently, in commercial processes, only materials having a basis weight of greater than or equal to 30 gsm have microspheres incorporated into them. An important advantage of the process of the present invention is the ability to impart increased opacity to products of lower basis weights and, specifically, to products with basis weights of 18 gsm of less and, more specifically, to products with

basis weights of 14 gsm to 18 gsm.

Other important advantages of tissue products formed according to the process of the present invention include decreased cost to manufacture, increased softness, retention of tensile strength, and increased absorbency.

Various tissue-making processes are known to those in the art. In particular, U.S. Patent No. 5,129,988 to Farrington, Jr.; U.S. Patent No. 5,772,845 to Farrington, Jr. et al.; and U.S. Patent No. 5,494,554 to Edwards et al. disclose various tissue-making methods and methods for forming multi-layered paper webs. Such patents are incorporated herein in their entireties by reference thereto.

Figure 1 is a schematic flow diagram of a conventional wet-pressed tissue making process useful in the practice of this invention, although other tissue making processes can also benefit from the method of this invention, such as thoroughdrying or other non-compressive tissue making processes. The specific formation mode illustrated in Figure 1 is commonly referred to as a crescent former, although many other formers well known in the papermaking art can also be used. Shown is a headbox 21, a forming fabric 22, a forming roll 23, a paper making felt 24, a press roll 25, a spray boom 26, a Yankee dryer 27, and a creping blade 28. Also shown, but not numbered, are various idler or tension rolls used for defining the fabric runs in the schematic diagram, which may differ in practice. As shown, the headbox 21 continuously deposits a stock jet 30 between the forming fabric 22 and felt 24, which is partially wrapped around the forming roll 23. Water is removed from the aqueous stock suspension through the forming fabric by centrifugal force as the newly-formed web traverses the arc of the forming roll. As the forming fabric and felt separate, the set web 31 stays with the felt and is transported to the Yankee dryer 27.

At the Yankee dryer, creping chemicals may be continuously applied in the form of an aqueous solution to the surface of the Yankee dryer on top of the residual adhesive remaining after creping. The creping chemicals can include one or more dry strength agents. The solution is applied by any conventional means, such as a spray boom 26 which evenly sprays the surface of the dryer with the creping adhesive solution. The point of application on the surface of the dryer is immediately following the creping doctor blade 28, permitting sufficient time for the spreading and drying of the film of fresh adhesive before contacting the web in the press roll nip.

The wet web 31 is applied to the surface of the dryer by means of the press roll or pressure roll 25 with an application force typically of about 200 pounds per square inch (psi). The incoming web is nominally at about 10% consistency (range from about 8 to about 20%) at the time it reaches the press roll. Following the pressing and dewatering step, the consistency of the web is at or above about 30%. The side of the web in contact with the surface of the Yankee dryer is referred to herein as the "dryer side" of the web. The opposite side of the web is referred to as the "air side" of the web. Sufficient Yankee dryer steam power and hood drying capability are applied to the web to reach a final moisture content of about 2.5% or less.

Also illustrated in Figure 1 is the white water recycle system. At the press roll nip, white water effluent 35 expressed from the wet web is collected in catch pan 36. Because of the presence of a substantial amount of water in the pressure roll nip, some of the dry strength agent is transferred from the surface of the Yankee into the white water, which also contains fines. The collected white water 37 drains into wire pit 38. Thick stock 40 having a consistency of about 2 percent is diluted with white water at the fan pump 39 to a

consistency of about 0.1 percent. The diluted stock 41 is subsequently injected into the headbox 21 to form the wet web.

The microspheres may be added anywhere in the wet end of the tissue making process. For example, the microspheres may be added to the headbox 21, prior to headbox 21 in a separate apparatus that then flows the microspheres into contact with the pulp furnish (sometimes referred to as stock suspension) in the headbox 21, or after the headbox 21 as a direct additive to the pulp furnish being carried between forming fabric 22 and felt 24.

Although other brands of microspheres may be utilized, one particular brand of microspheres is sold under the name EXPANCEL® by Akzo Nobel. EXPANCEL® microspheres consist of hollow, white, spherically-formed polymer particles encapsulating a blowing agent (for example, liquid isobutane) under pressure. The microspheres generally have a mean diameter of about 10-12 μm. The thermoplastic shell softens when heated so that the gasification of the blowing agent expands the microspheres to a final volume that is from 30 to more than 60 times larger than the original volume at constant weight. Additional features of EXPANCEL® are discussed in Technical Bulletin No. 13 for EXPANCEL® Microspheres in Paper and in Ö. Söderberg, "Expandable Microspheres in Board," *World Pulp & Paper Technology*, 1995/96, at 143, both of which are incorporated herein in their entireties by reference thereto.

These microspheres start to expand upon heating above a given temperature, depending on the chemistry of the copolymer. In a particular embodiment of the present invention, EXPANCEL® 551-20 was employed, and it began expanding at a temperature of from about 93°C to about 98°C. However, other grades of EXPANCEL® products (and other brands of expandable microspheres) may expand at lower or higher temperatures and may, thus, be suitable for

particular engineered applications.

The surface of the microsphere shells, a copolymer of acrylonitrile and vinylidene chloride, is very electronegative or has a strong anionic character. In fact, the microspheres and the fibers themselves are anionically charged. Thus, cationic polymeric additives may be used in the process of the present invention to achieve good retention. In particular embodiments of the present invention, the cationic retention aid used is a cationic polyacrylamide; however, any number of known cationic retention aids may be used.

Suitable cationic polyamide resins include the water-soluble polymeric reaction products of an epihalohydrin, preferably epichlorohydrin, and a water-soluble polyamide having secondary amine groups derived from polyalkylene polyamine and a saturated aliphatic dibasic carboxylic acid containing from about 3 to 10 carbon atoms. The water soluble polyamide contains recurring groups of the formula:

$$-NH(C_nH_{2n}HN)_x-CORCO-$$

where n and x are each 2 or more and R is the divalent hydrocarbon radical of the dibasic carboxylic acid. An important characteristic of these resins is that they are phase compatible with polyvinyl alcohol. Suitable materials of this type are commercially available under the trademarks KYMENE® (Hercules, Inc.) and CASCAMID® (Borden) and are more fully described in U.S. Patent No. 2,926,116 issued to Keim, U.S. Patent No. 3,058,873 issued to Keim et al., and U.S. Patent No. 4,528,316 issued to Soerens, all of which are herein incorporated by reference. The creping adhesive also preferably includes polyvinyl alcohol. The amount of the thermosetting cationic polyamide resin in the creping composition, on a solids weight

percent basis, can be from about 10 to about 80 percent, more specifically from about 20 to about 60 percent.

EXAMPLES

The present invention may be understood by reference to the following Examples, without being limited thereto. The Examples were performed in order to demonstrate the opacity enhancement in fibrous structures.

Examples 1-5

These five Examples demonstrate the increased opacity and decreased density of softwood kraft pulp sheets after the addition of thermally expandable microspheres. Specifically, in these Examples, EXPANCEL® 551-20 was used as the source of the thermally expandable microspheres. Also, the retention of the EXPANCEL® onto the sheets was facilitated by the addition of a cationic polyacrylamide retention aid (Nalco 7520), and the handsheets were produced according to a TAPPI Standard Procedure T205 sp-95 (with the only deviation from the standard being the use of a Valley Steam hot plate at a temperature of 213 $\pm$ 2°F instead of the typical pressing procedure).

The handsheet mold used in this standard procedure was a square wire mesh of plain weave bronze. Sufficient amounts of a thoroughly mixed pulp stock were used to produce handsheets having a basis weight of 60 gsm. As the handsheets were being formed, two different amounts of the EXPANCEL® product were used as indicated in the tables below. In addition, a control handsheet without microspheres was also formed. The test handsheets were not pressed.

A Valley Steam hot plate was used as the dryer for these test handsheets. This hot plate has a convex surface and is covered with a standard canvas held down by a lead filled brass tube. The pulp

sheets were placed, wire side up, on the polished surface of the sheet dryer, wherein the canvas was carefully lowered over the sheet. A weight was fastened to the lead filled brass tube. Most tested handsheets were dried for 2 minutes; however, two of the five Examples herein were dried for five minutes to verify that the microspheres had expanded to their full expansion capacity. The dried sheets were then removed from the dryer and trimmed to the desired size.

The handsheets described above were tested for various physical characteristics including bulk, scattering coefficient, and opacity levels. The data collected appears in Table I below:

Table I

Example No.	Minutes Dried	EXPANCEL %	Bulk (cm^3/g)	Scattering Coefficient (m^2/kg)	Opacity
1	2.0	0.0%	1.729	34.95	76.1
2	2.0	0.5%	1.907	36.41	79.6
3	5.0	0.5%	2.117	41.45	81.4
4	2.0	1.0%	2.053	40.69	81.1
5	5.0	1.0%	2.072	41.20	81.8

The bulk of the handsheets is the inverse of the apparent density of those handsheets as evidenced by the units of cm^3/g.

The scattering coefficient of each handsheet was determined after performing an industry standard test (TAPPI Test Method T-220 sp-96) for measuring light-scattering coefficients. In this procedure, an opacimeter (Technibrite Micro TB-1C available from Technidyne

Corporation of New Albany, Indiana) is used, and the working standard of reflectance is calibrated to absolute scale. The working standard is then placed over the opening of the opacimeter, and the instrument is adjusted to read the value of the absolute reflectance of the working standard. Readings are obtained by placing each sheet in the opacimeter with its smooth side against the black body and reading the reflectivity without adjustment of the instrument. Light scattering and opacity readings are taken and performed according to TAPPI Test Method T519 om-96.

The opacity measurements of each handsheet were taken and recorded above. Opacity is weight dependent and thus is measured somewhat differently than bulk and scattering coefficient as explained above.

The measurement of opacity is determined by a ratio of reflectance measurements. The opacity of the sheet is influenced by thickness. The method used for the opacity measurements was TAPPI Test Method T-425 om-96. The essential principle of this method of opacity determination is as follows: the reflectance of paper when combined with a white backing is higher than that of paper when combined with a black backing because, in the former case, light transmitted through the imperfectly opaque sheet is largely reflected by the white backing, and a portion of the light is transmitted through the paper a second time thus increasing the total reflection. The opacity tests were performed with an opacity meter equipped with an accurate linear or a corrected photometric system according to the aforementioned TAPPI Test Method T519 om-96.

The data collected in Table I reflects the increased opacity and improved scattering coefficient with the addition of the EXPANCEL® 551-20 thermally expandable microspheres. Example 1, the control Example, had the lowest bulk, scattering coefficient, and opacity

rating of all five Examples. Furthermore, Example 5, wherein 1.0 % of the EXPANCEL® was added and wherein the handsheet was dried for five minutes instead of two, exhibited the highest opacity rating of the five Examples. Also, the tissue product of Example 5 was not as bulky as the product of Example 3 wherein 0.5 % of the EXPANCEL® was added and wherein the product was dried for five minutes. Thus, with the addition of EXPANCEL® to the handsheets, both opacity and scattering coefficient significantly increased, while the sheets did not experience a large increase in bulk.

These and other modifications and variations to the present invention may be practiced by those of ordinary skill in the art, without departing from the spirit and scope of the present invention, which is more particularly set forth in the appended claims. In addition, it should be understood that aspects of the various embodiments may be interchanged both in whole or in part. Furthermore, those of ordinary skill in the art will appreciate that the foregoing description is by way of example only, and is not intended to limit the invention so further described in such appended claims. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained therein.